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Department of Geodetic Science and Surveying

Terrestrial Gravity Data Analysis for Interim Gravity Model Improvement

Status Report No. 1

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1. Introduction

This is the first status report for the research effort that was started on June 30, 1986. The basic theme of this study is to develop appropriate models and adjustment procedures for estimating potential coefficients from terrestrial gravity data. The plan is to use our latest gravity data sets to produce coefficient estimates as well as to provide normal equations to NASA for use in the TOPEX/POSEIDON gravity field modeling program.

2. The Status of the Research

Mr. Nikos Pavlis, a Graduate Research Associate, is carrying out the research for this project as part of his master's thesis work. Pavlis has prepared the following report.

"The purpose of this study is to examine an optimum way of utilizing the terrestrial gravity information in combination with the satellite data, for the computation of a highly accurate gravity field model to be used for the TOPEX/POSEIDON mission. The final product of this work will be a set of normal equations referring to a low degree ($\leq$ 50) potential coefficient set, to be combined with the satellite derived normals at NASA/GSFC. The task is divided into four parts:

(A) Theoretical investigation of the problem and mathematical formulation of the solution.

(B) Development of the necessary software to perform the solution.

(C) Implementation of the software on the CRAY X-MP supercomputer at the Pittsburgh Supercomputing Center (PSC).

(D) Final solution and validation of the quality of the result.

What follows is a brief description of what has been done since the start of the project:

A. The mathematical model that relates gravity anomalies, Δg, with potential coefficients $\begin{Bmatrix} \bar{C}^*_{nm} \\ \bar{S}_{nm} \end{Bmatrix}$ is :

$$\Delta g_Q + \delta g_A = \frac{GM}{r_Q^2} \sum_{n=2}^{N_{max}} (n-1) \left(\frac{a}{r_Q}\right)^n \sum_{m=0}^{n} \left[\bar{C}^*_{nm} \cos m\lambda_Q + \bar{S}_{nm} \sin m\lambda_Q\right] \bar{P}_{nm} (\cos\theta_Q)$$

$$+ \varepsilon_h + \varepsilon_\gamma \tag{1}$$

where:

(a) Point Q refers on the telluroid.

(b) δg_A is the atmospheric correction to be applied to Δg_Q.

(c) $\varepsilon_h = e^2 \sin\theta_Q \cos\theta_Q \frac{1}{r_Q}\left(\frac{\partial T}{\partial \theta}\right)_Q$ (2)

(d) $\varepsilon_\gamma = \left[6J_2 \frac{a^2}{r_Q{}^3} P_2(\cos\theta_Q) - \frac{3\omega^2 r_Q{}^2}{GM}\sin^2\theta_Q\right] T_Q$ (3)

The quantity Δg_Q is considered point surface free air anomaly in the Molodensky sense. The above formulation takes into account the ellipsoidal effects to the order of e^2. Since such effects are long wavelength features they can be computed from an existing truncated field and applied as reductions to the gravity anomalies. Passing from point values to mean values we come up with:

$$\bar{\Delta g}_i + \delta g_{A_i} + \delta g_{E_i} = \frac{GM}{\bar{r}_i{}^2}\frac{1}{\Delta\sigma_i}\sum_{n=2}^{N_{max}}(n-1)\left(\frac{a}{\bar{r}_i}\right)^n \sum_{m=0}^{n}\left[\bar{C}^*_{nm} IC_m + \bar{S}_{nm} IS_m\right] I\bar{P}_{nm} \quad (4)$$

where i denotes the block where $\bar{\Delta g}$ refers to and:

(a) $\delta g_{E_i} = -(\varepsilon_{h_i} + \varepsilon_{\gamma_i})$ (5)

(b) $\bar{r}_i$ is the mean geocentric radius of the block.

(c) $\Delta\sigma_i = (\lambda_E - \lambda_W)\int_{\theta_N}^{\theta_S}\sin\theta d\theta$ (area of the block) (6)

(d) $IC_m = \int_{\lambda_W}^{\lambda_E}\cos m\lambda d\lambda$, $IS_m = \int_{\lambda_W}^{\lambda_E}\sin m\lambda d\lambda$ (integrated cosine and sine) (7)

(e) $I\bar{P}_{nm} = \int_{\theta_N}^{\theta_S}\bar{P}_{nm}(\cos\theta)\sin\theta d\theta$ (integrated fully normalized associated legendre functions) (8)

The gravity material to be used are the 1°x1° terrestrial mean gravity anomalies, taken from the June 1986 update of R. H. Rapp's data bank. The **geocentric radii are computed using the 1°x1° mean elevations** (OCT85.MELEV). Equation (4) after the application of δg_A, δg_E takes the form:

$$\bar{\Delta g}^*_i = \frac{1}{\Delta\sigma_i}\frac{GM}{\bar{r}_i{}^2}\sum_{n=2}^{N_{max}}(n-1)\left(\frac{a}{\bar{r}_i}\right)^n \sum_{m=0}^{n}\left[\bar{C}^*_{nm} IC_m + \bar{S}_{nm} IS_m\right] I\bar{P}_{nm} \quad (9)$$

with $\bar{\Delta g}^*_i = \bar{\Delta g}_i + \delta g_{A_i} + \delta g_{E_i}$ (10)

Since (9) is linear with respect to $\begin{Bmatrix}\bar{C}^*_{nm}\\ \bar{S}_{nm}\end{Bmatrix}$ we use the adjustment model:

$$V = AX - L \quad (11)$$

to estimate $X = \begin{bmatrix}\bar{C}^*_{nm}\\ \bar{S}_{nm}\end{bmatrix}$ from $L = \left[\bar{\Delta g}^*_i\right]$

The final product of this work will be:

$$N = A^T P A \ , \ U = A^T P L \ , \text{ where} \tag{12}$$

P is the weight matrix. It will be diagonal with $P_i = \frac{1}{\sigma_i^2}$ where σ_i are the accuracy estimates of the June '86 data bank. The current plan is to assume P is a diagonal matrix although we know it is not in reality.

B. The necessary software to implement the above described algorithm has been written and tested on the IBM-3081D at the Ohio State University. Simulated data have been used to test the recovery of the coefficients for expansions up to $N_{max} = 12$. The descrepancies between the recovered and original coefficients were always 5 orders of magnitude less than the order of the coefficient.

C. The program package has been modified to be able to take as much as possible advantage of the vectorization in the supercomputer. At this point test runs are being done in order to check the implementation of the package on the Cray."

3. Future Progress

A large number of tests are planned in the next reporting period. These tests will try to understand the variability of the potential coefficient results depending on data distribution and data accuracy. We will be preparing normal equation tapes to be sent to NASA (Goddard) for use in the normal equations developed from satellite data. Our main computer runs will be made using a CRAY computer grant from the University of Pittsburgh.

4. Personnel

The Principal Investigator of this project is Professor Richard H. Rapp. The bulk of this study is being carried out by Mr. N. Pavlis, Graduate Research Associate in the Department of Geodetic Science and Surveying.

5. Other

Both Professor Rapp and Mr. Pavlis attended the TOPEX Gravity Team Meeting in November 1986 at the Goddard Space Flight Center. Professor Rapp presented a paper "Surface Gravity Data" that describes the data going into the new solutions. The paper will appear in the proceedings of the meeting.